



## Ancillary services from wind power plants

Research results

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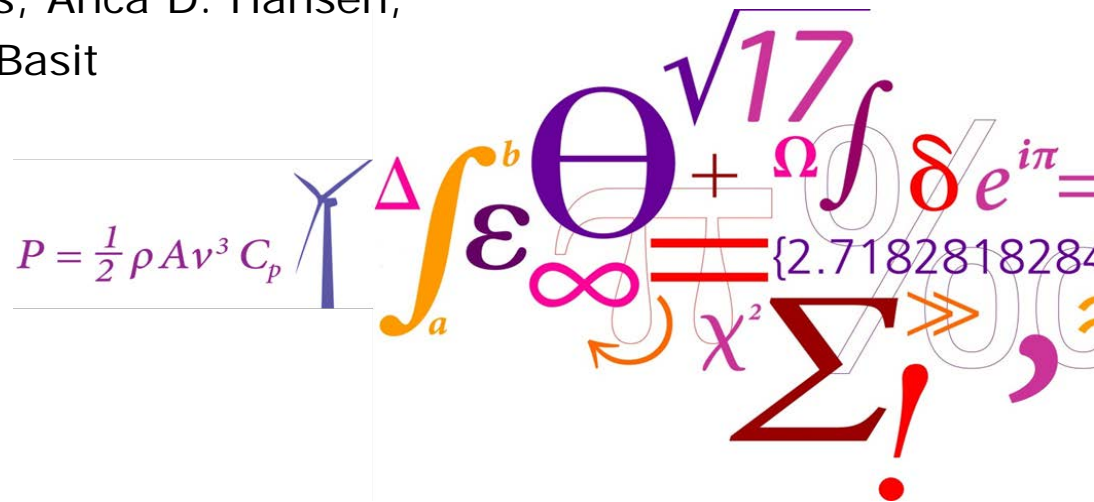
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# Ancillary services from wind power plants

## - Research results

Poul Sørensen, Nicolaos Cutululis, Anca D. Hansen,  
Müfit Altin, Lorenzo Zeni, Abdul Basit



# Program outline

## Ancillary Services: Research Results From Wind Power Plants

- ***Definitions and requirements*** for ancillary service
- ***Technical capabilities*** of wind power plants to provide ancillary services - ***state-of-the-art industry and R&D*** (simulation based) perspectives
- What are the ***economic incentives and barriers*** to providing ancillary services?
- What are the ***next steps*** for researchers, developers, system operators and turbine manufacturers to allow further penetration of wind into European grids?

# Definitions of ancillary services

- CIGRÉ report - overview of International Practices
  - **definitions** for ancillary services can **differ significantly** based on who is using the terms. While some definitions emphasize the importance of ancillary services for **system security and reliability**, others mention the use of ancillary services to **support electricity transfers from generation to load** and to **maintain power quality**
- Some TSOs are including **more specific types** of ancillary services **than others** because
  - **differences in the definitions** (above)
  - some of the required properties of the generation plants are **embedded in conventional power plants** using directly grid connected synchronous generators.
  - **new ancillary service products** seem to pop up in power systems **with large scale penetration of renewables**.

# Requirements for – and types of – ancillary services

- Active power **reserves** (using ENTSO-E glossary)
  - Frequency containment reserves (FCR)
  - Frequency restoration reserves (FRR)
  - Replacement reserves (RR)
- Properties required to **maintain** power system **stability** today (Energinet.dk terminology)
  - Short-circuit power
  - Continuous voltage control
  - Voltage support during faults
  - Inertia
- **Possible additional** ancillary service **products** (research references)
  - Fast frequency response (and inertia support)
  - Synchronising power
  - Power oscillation damping
  - Black-start capability

# State of the art technical capabilities in industry

- Horns Rev 2002 (Kristoffersen et.al.) according to first DK technical requirements
  - Primary frequency control
  - Secondary frequency control
  - Reactive power neutral
- Today +
  - Continuous voltage control
  - Voltage support during faults
  - “Inertia” under development – verification?



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## Cost and value of ancillary services

Nicolaos A. Cutululis – DTU Wind Energy  
Herning, 26 March 2014



**REservices**  
ECONOMIC GRID SUPPORT FROM VARIABLE RENEWABLES

Supported by  
**INTELLIGENT ENERGY**  
EUROPE 



# RESERVICES CONSORTIUM

[www.reservices-project.eu](http://www.reservices-project.eu)

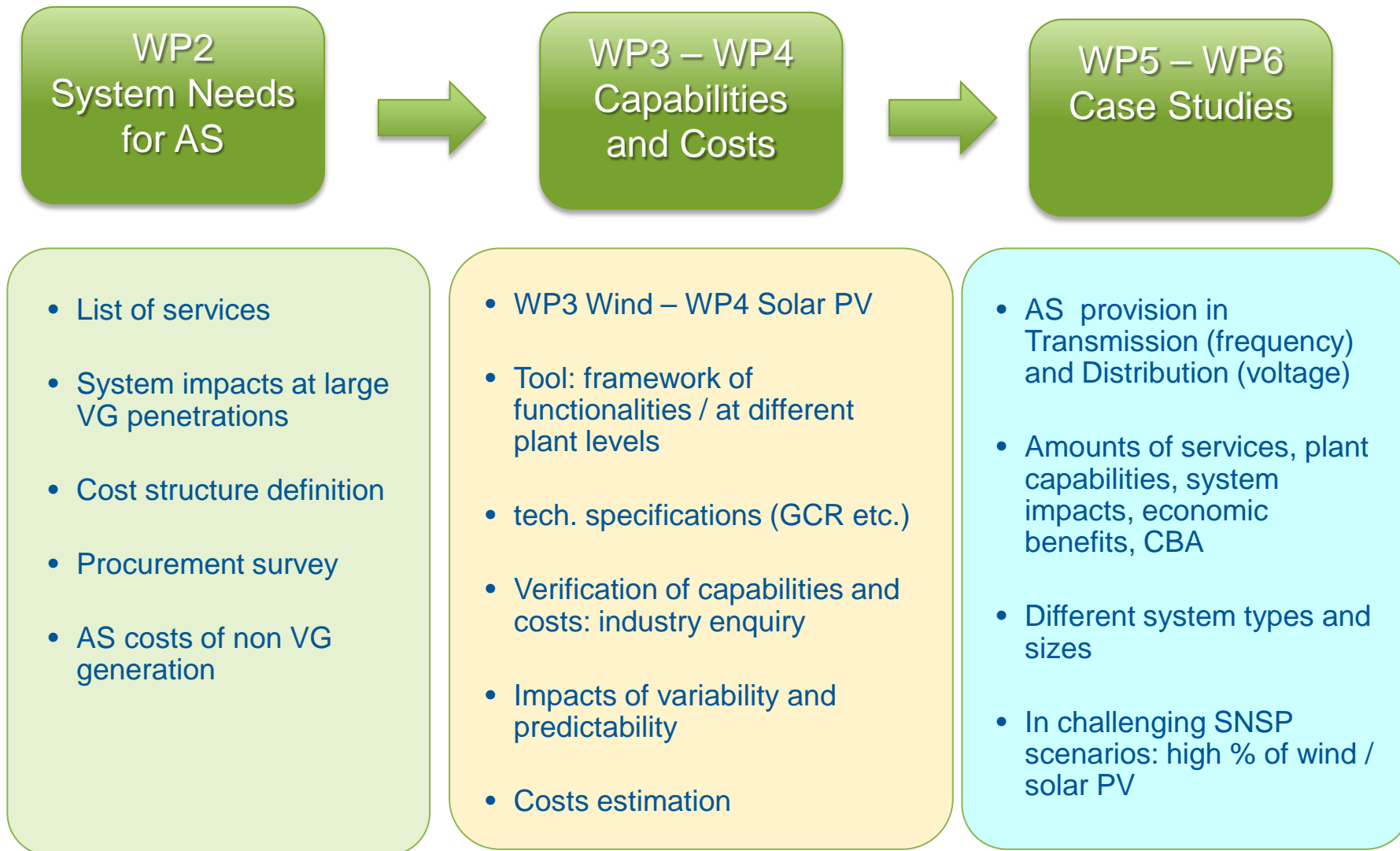
Sharon Wokke  
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DTU Wind Energy  
Department of Wind Energy

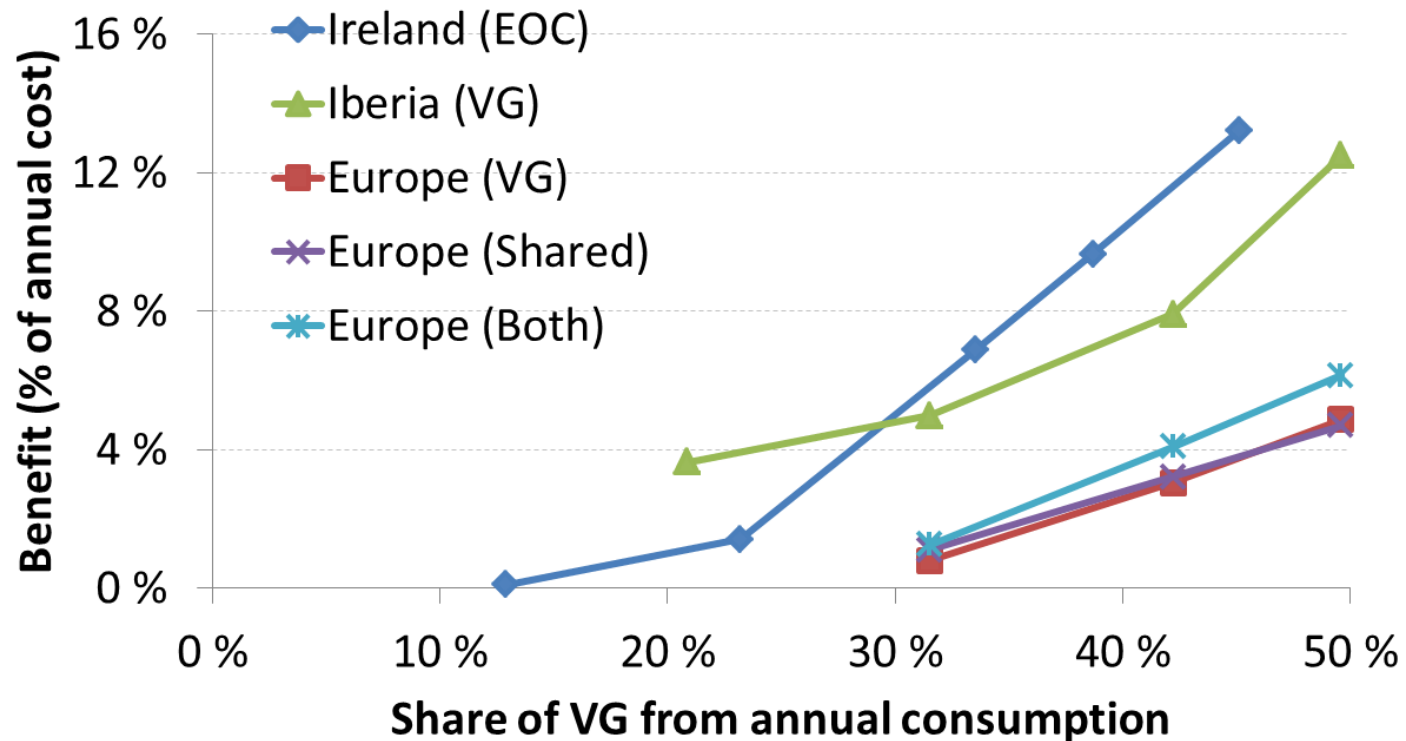






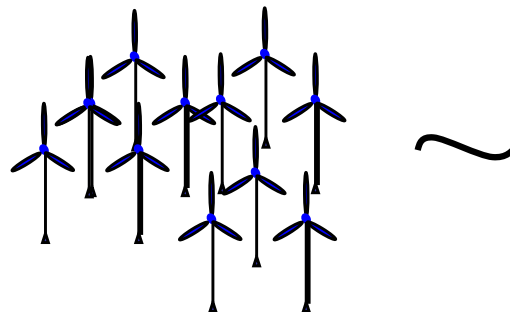
- Results from three case studies:
  - **Ireland** – based mainly on the results from several multi-year research programmes (Facilitation of Renewables and DS3); additional investigation of SS costs
  - **Iberia** – using WILMAR, 6 reg. for ES and 1 for PT; all thermal units represented (no aggregation); some agg. for hydro; VG agg. per region
  - **Europe** – 10 countries around North Sea and Baltic; based on TWENTIES scenarios; focus on cross border sharing of frequency reserves

## Benefit of VG in frequency support (cases have different assumptions)



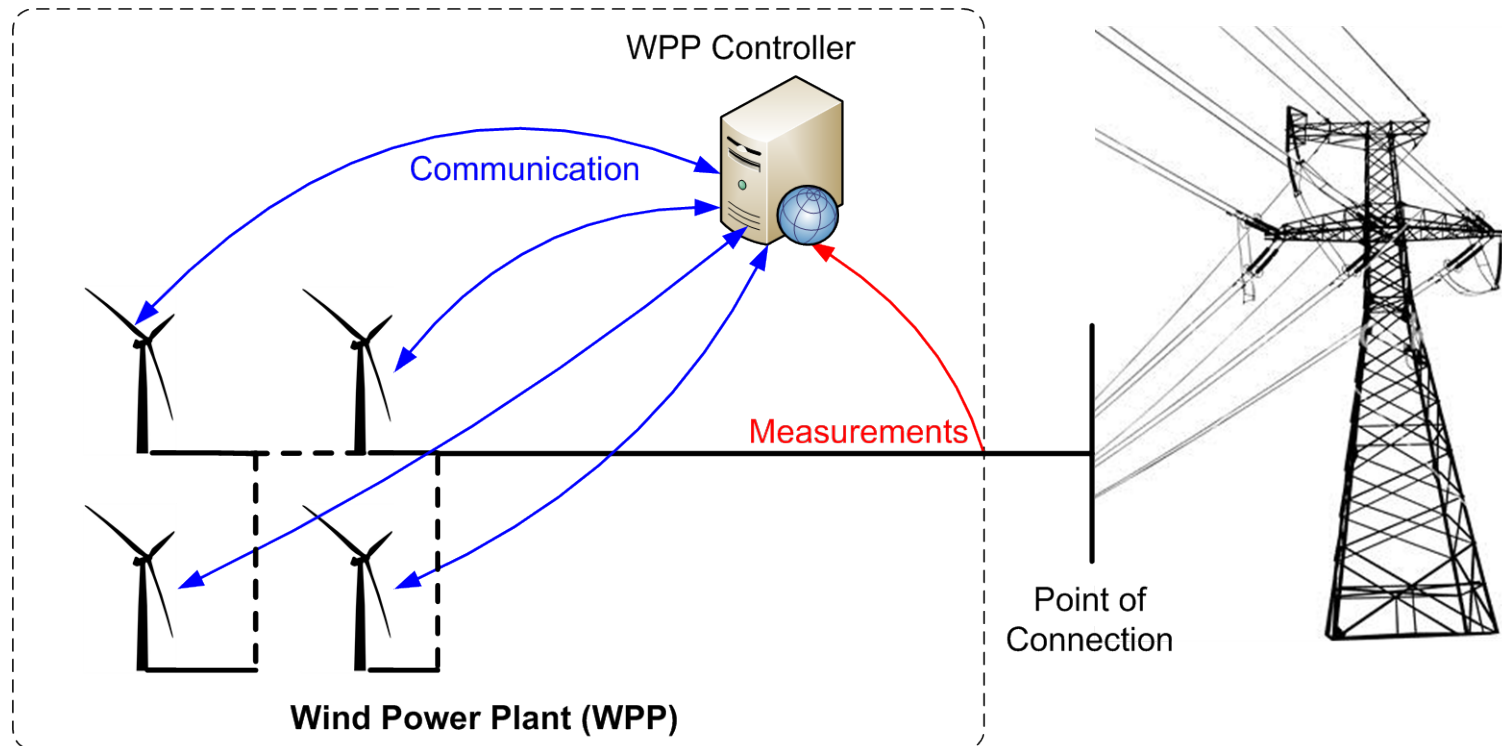
# EASEWIND

- Long title:
  - Enhanced Ancillary Services from Wind Power Plants
- Objective
  - to develop technical solutions for enabling wind power to have similar power plant characteristics as conventional generation units.
- Funding: ForskEL
- Consortium:
  - Vestas Technology R&D
  - DTU Wind Energy
  - DTU Compute
  - AAU IET

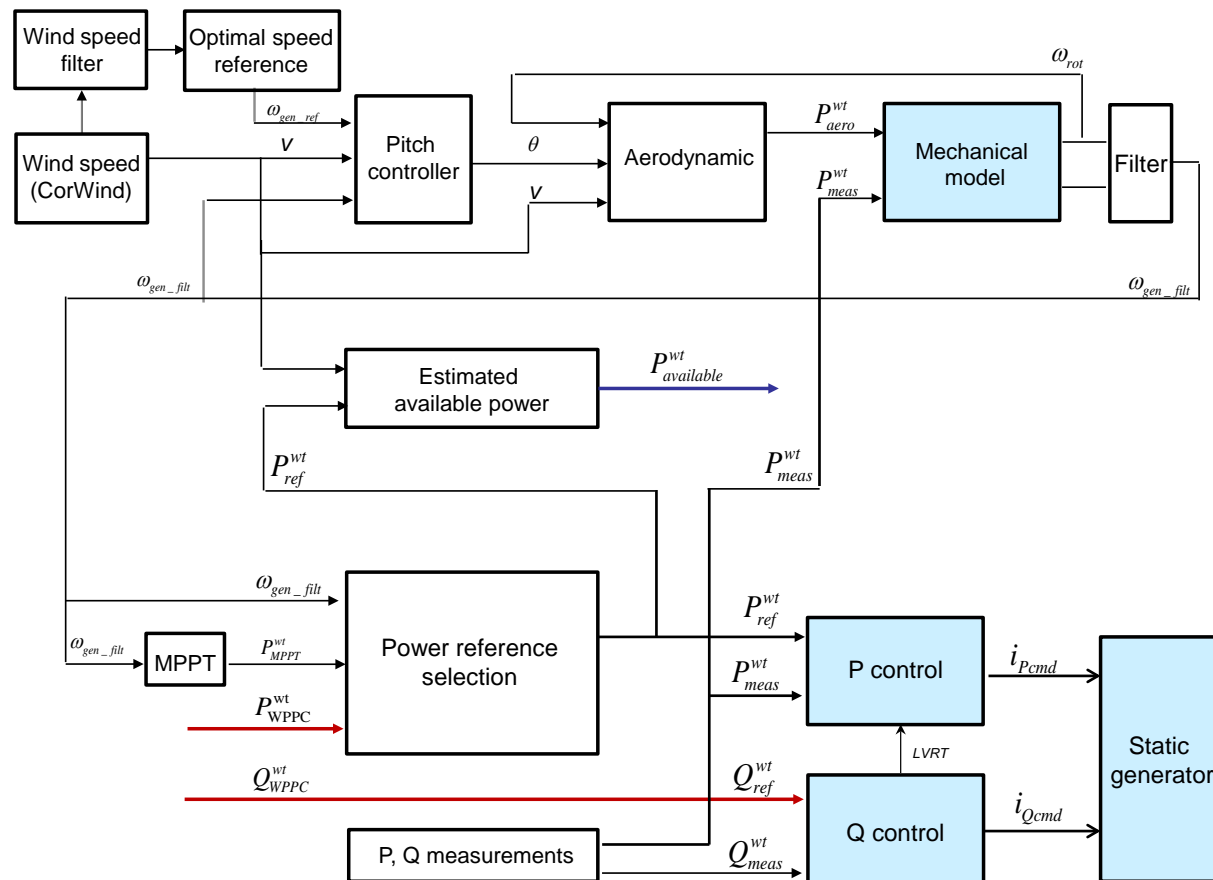


# Ancillary services from wind power plants

The ancillary services from wind power plants are ***supported by communication and control*** at the power plant level.

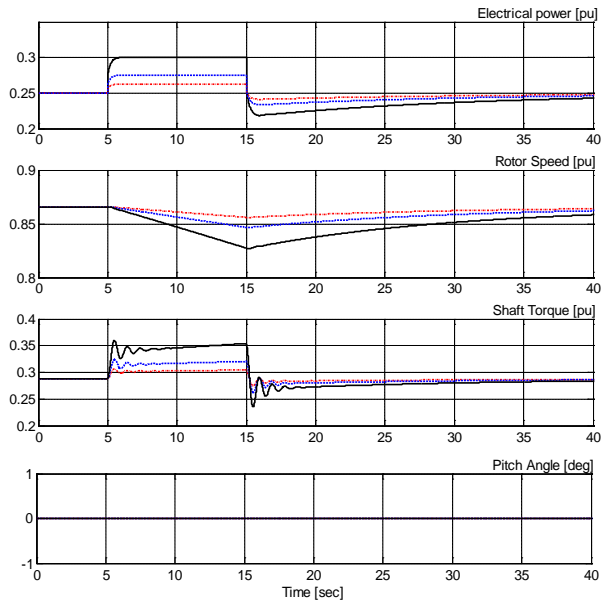


- follows the basic structure of the **IEC standard Type IV** wind turbine model
- includes additional adjustments to reflect the dynamics relevant for active power and grid frequency control capabilities.

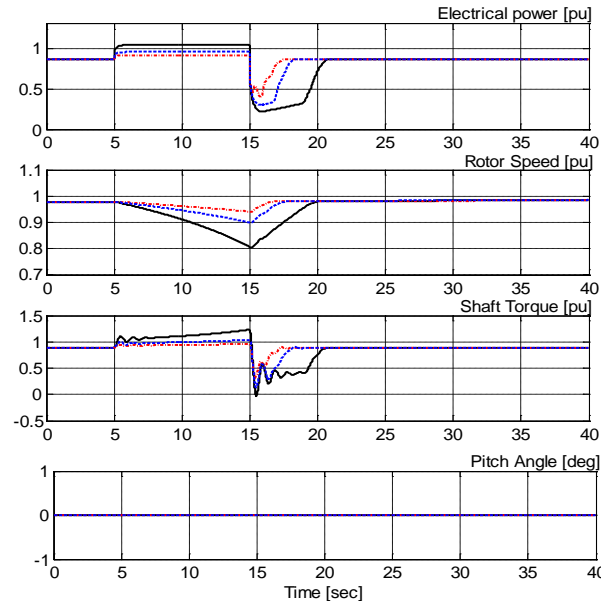


# Short-term overproduction capability

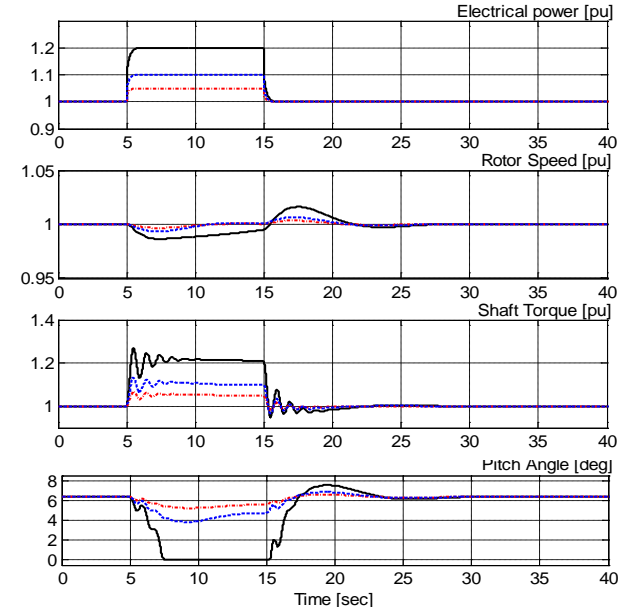
Wind speed 0.6pu



Wind speed 0.93pu



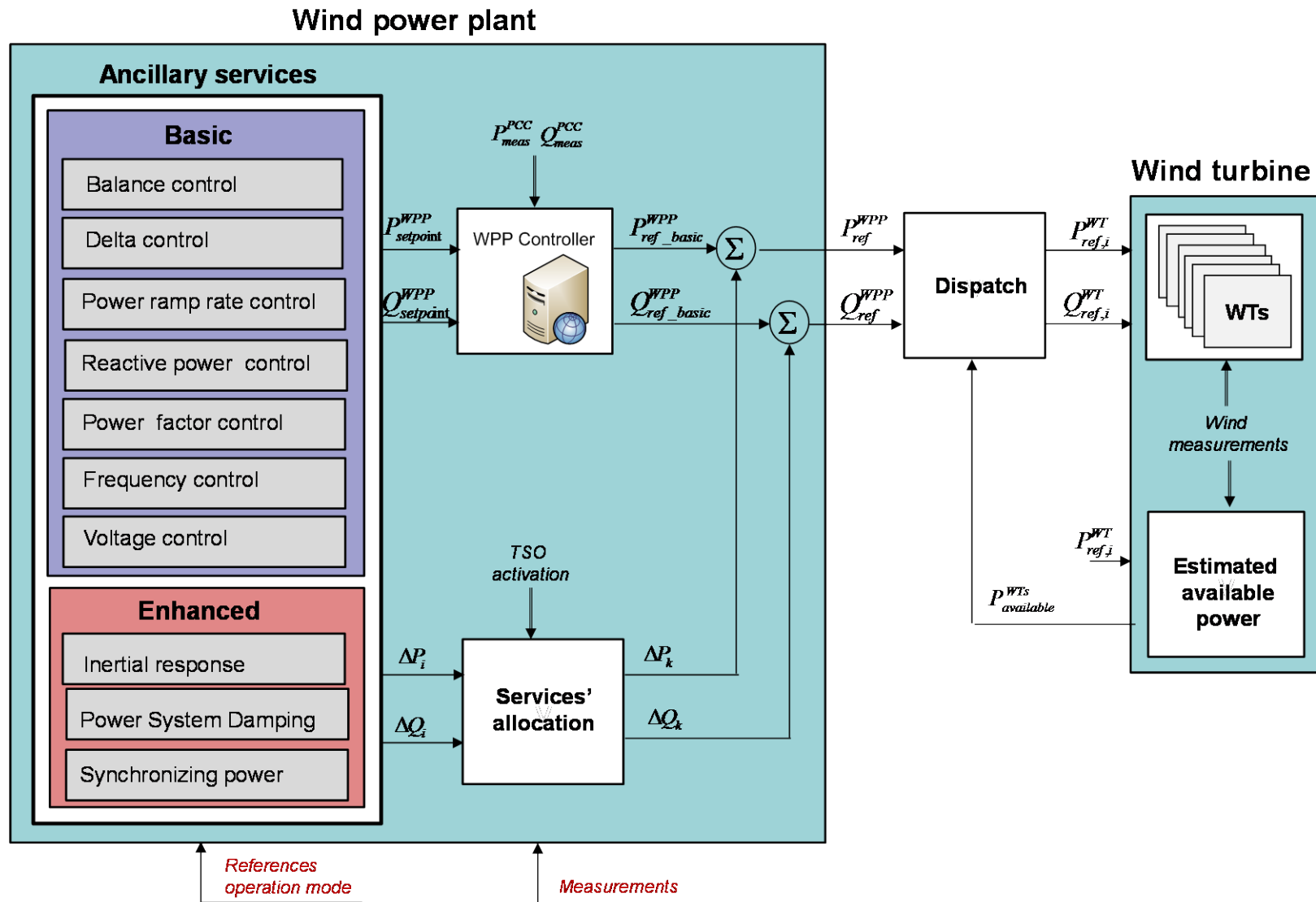
Wind speed 1.1pu



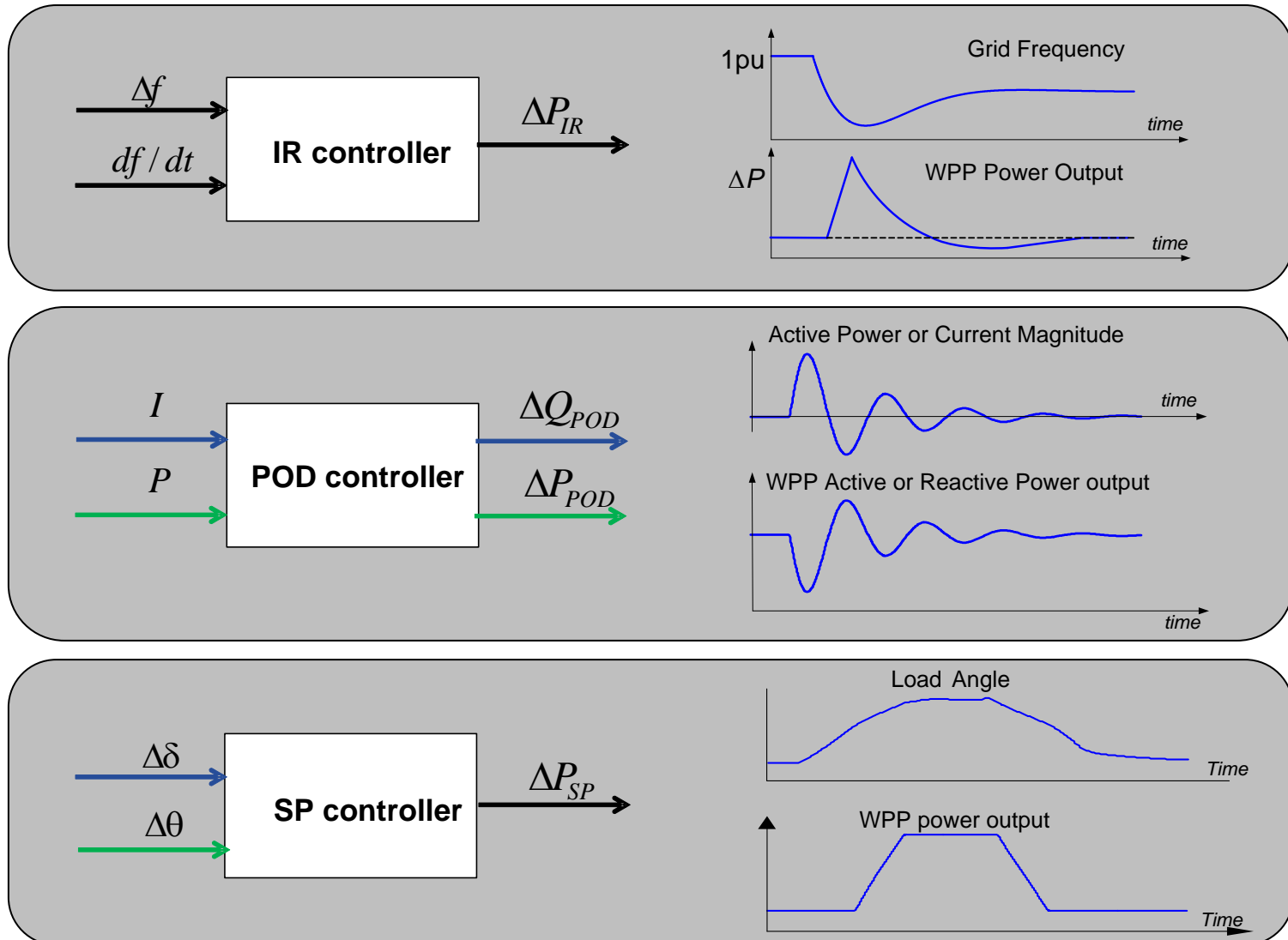
- Below rated wind speed, the overproduction is followed by **recovery period**
- The higher the wind speed, the **shorter** the recovery period
- The higher the overproduction power:
  - the longer the recovery period and the larger the power underproduction -> **frequency stability** might be affected
  - the higher the shaft **torque** -> high mechanical stress of the turbine
- No power recovery needed above rated wind speed



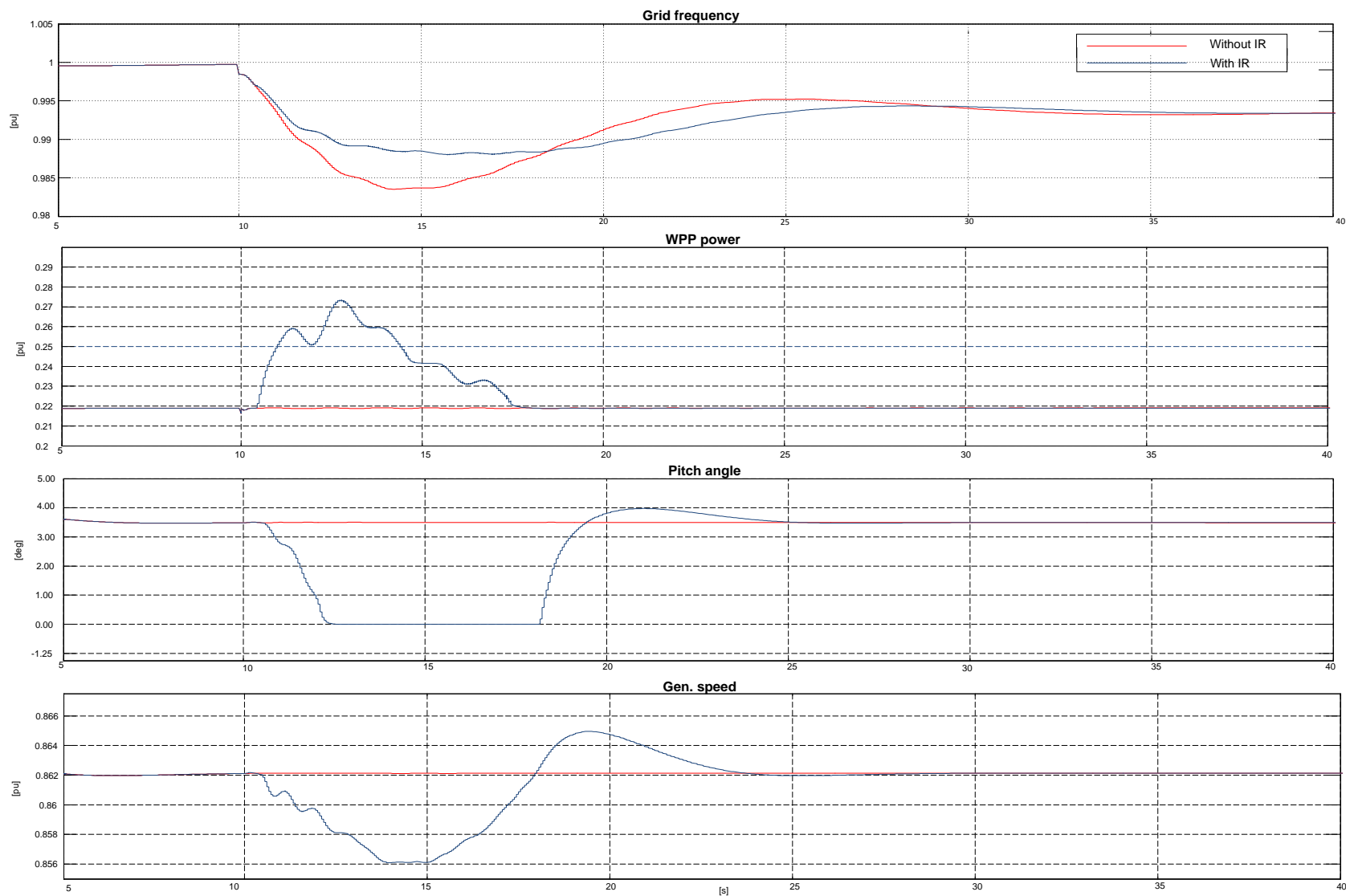
# Wind power plant control architecture



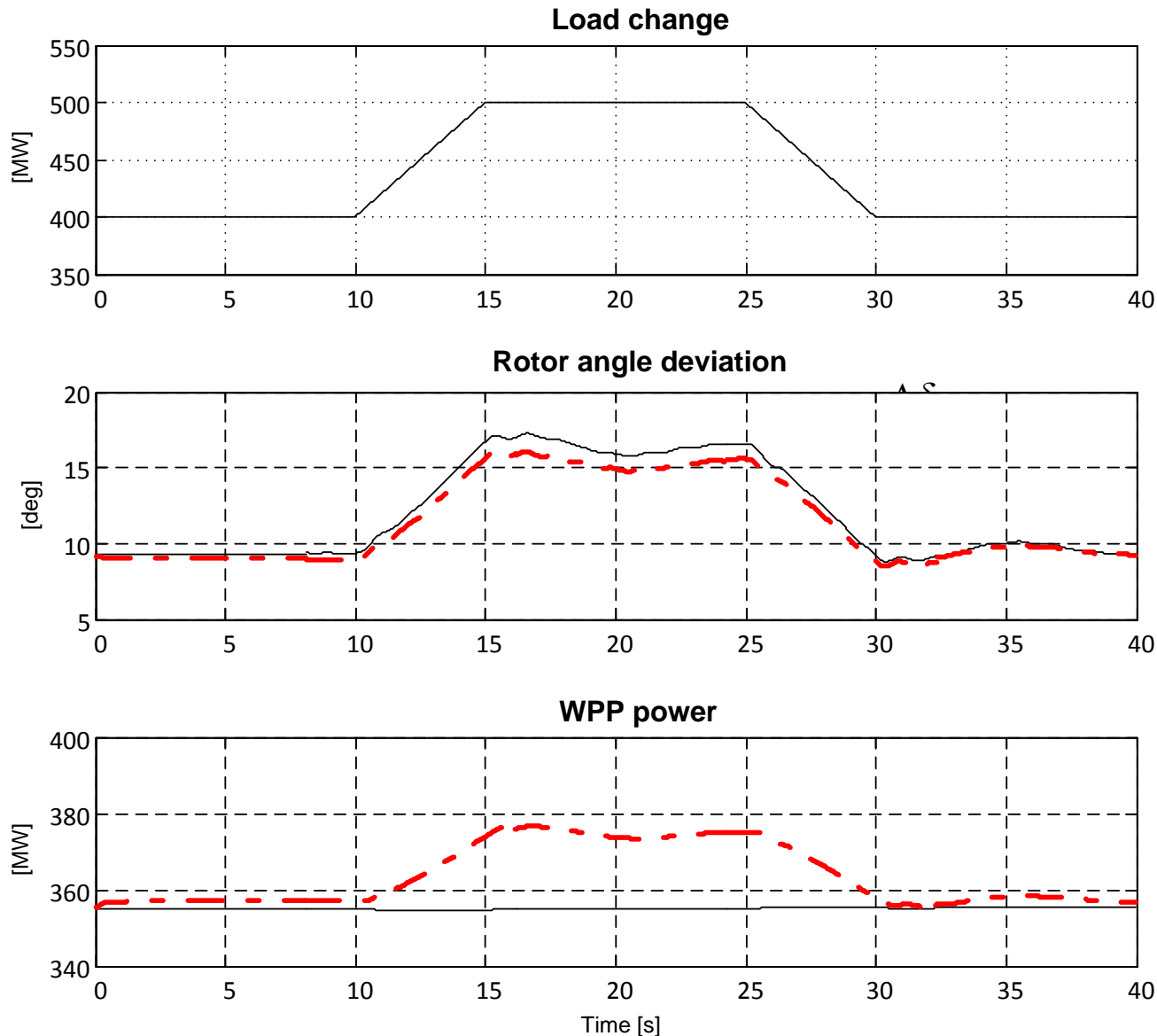
# Enhanced ancillary services

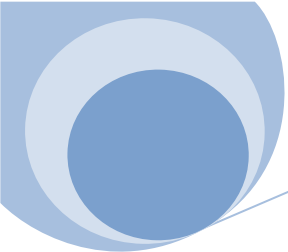


# WPP Inertial response capability



# WPP synchronise power capability





# OffshoreDC



norden

Nordic Energy Research

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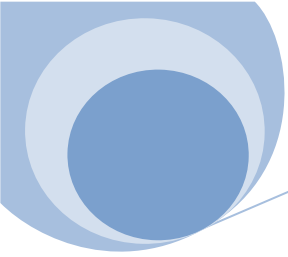
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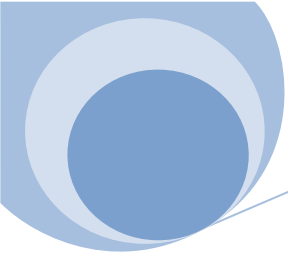
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# **WP 3 – Communication and control in clusters of wind power plants connected to offshore HVDC grids**

PhD student: Lorenzo Zeni



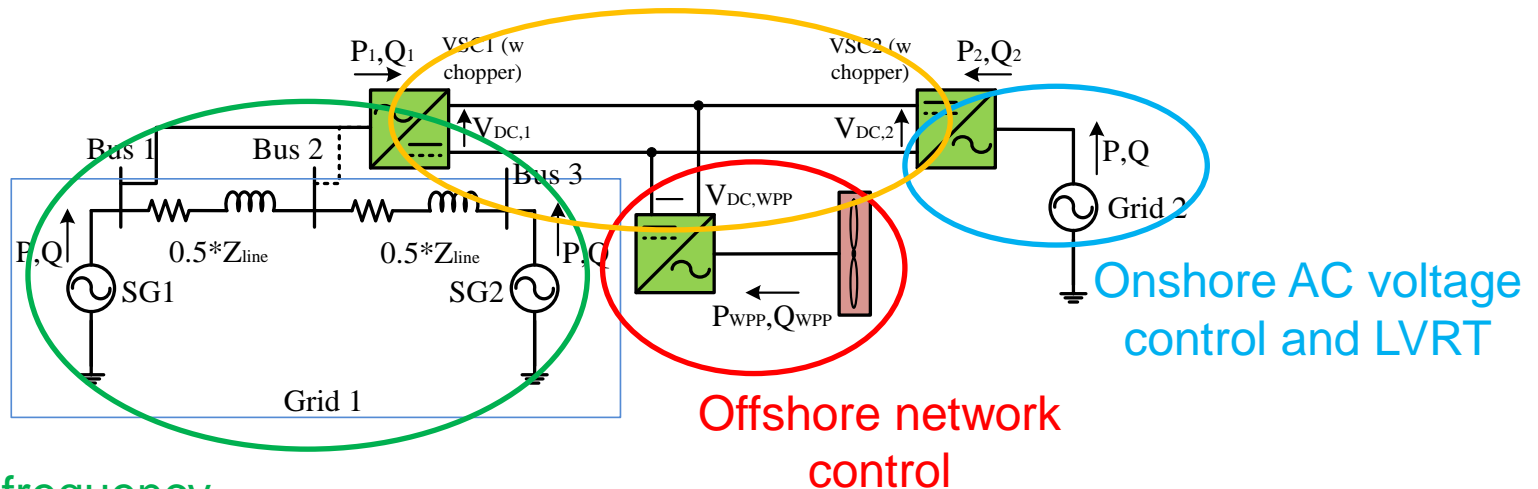


## Results – status

L. Zeni et.al. From paper in Cigré session 2014

Investigation on system services provision

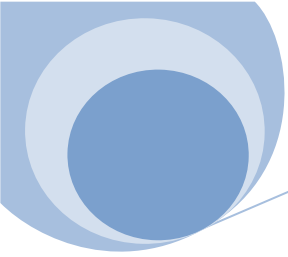
DC voltage control



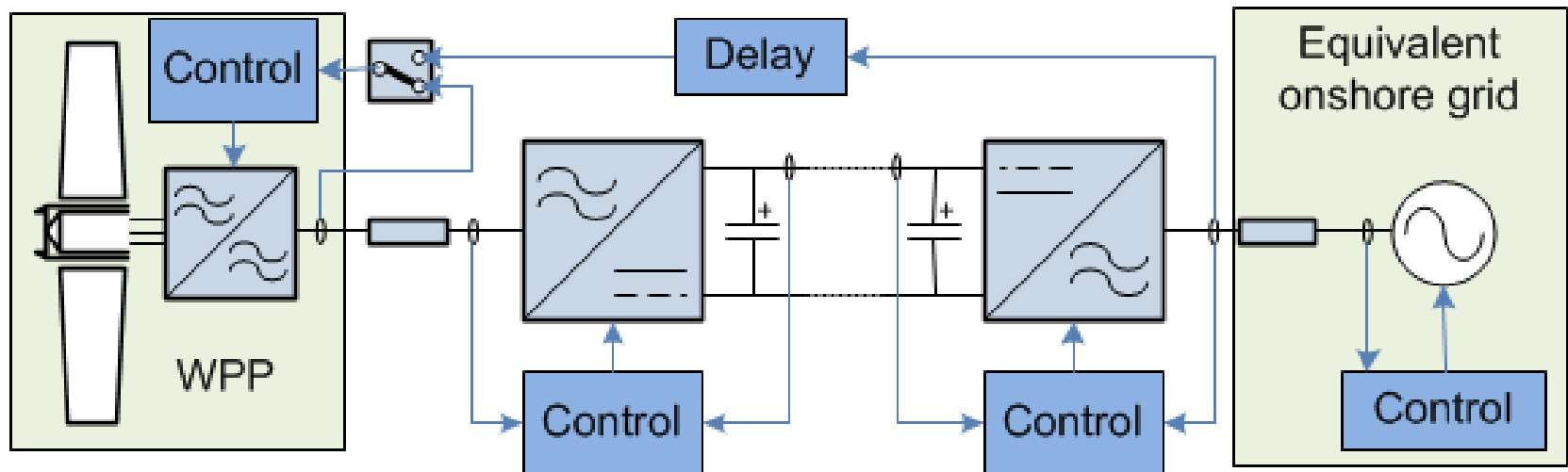
Onshore frequency  
control and power  
oscillation damping

Important results obtained and lines for future work  
were drawn.



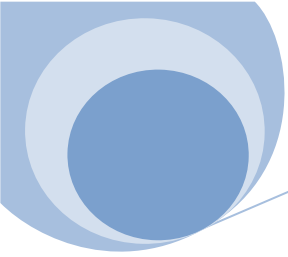


## Frequency support through HVDC P2P example

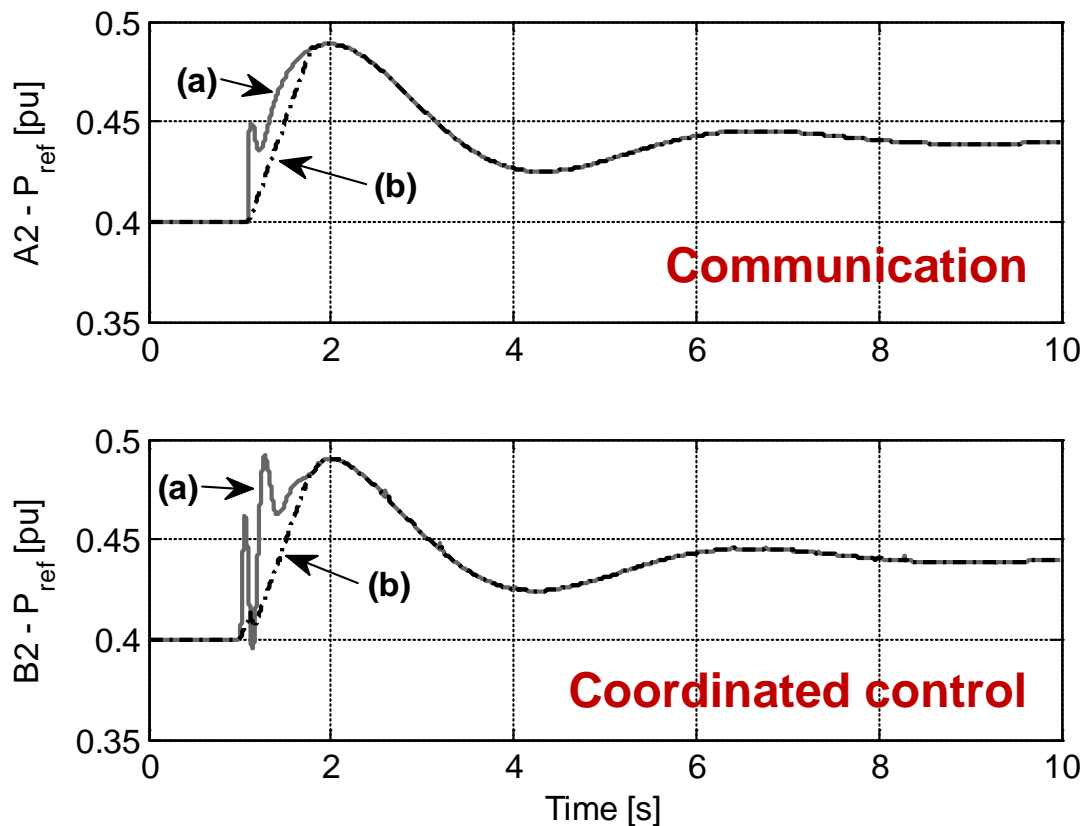


Two strategies are compared:

1. Communication-based control (with communication delay)
2. Coordinated control mirroring the frequency in DC voltage

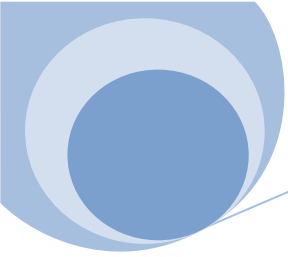


## On the inertial contribution



Power reference to WPP  
(a) From controller  
(b) Ramp-limited

The initial power support is heavily limited by the ramp limiter (0.1 pu/s):  
*relaxation of this figure?*

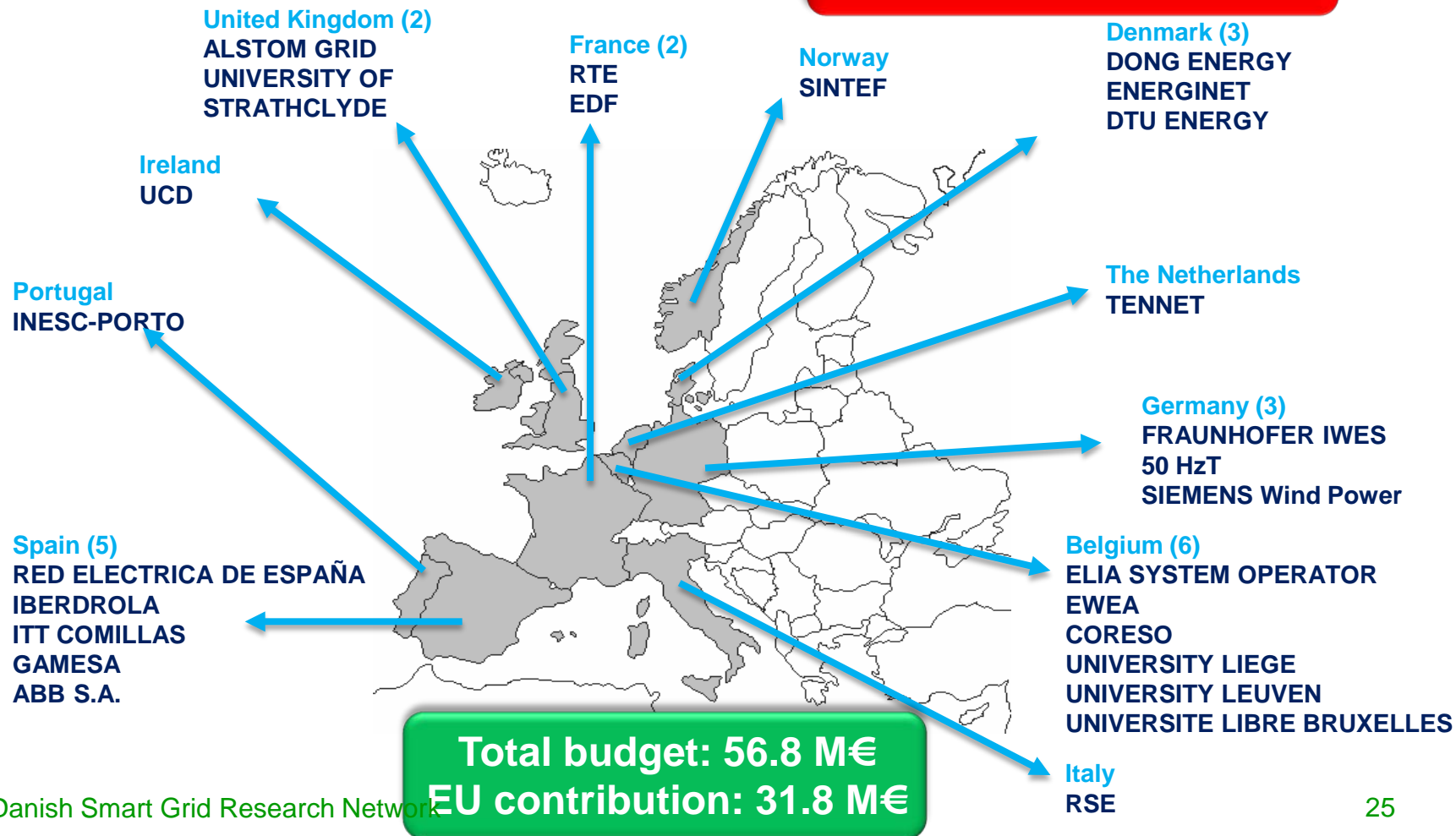


## Conclusions

- Onshore frequency variations ***can be mirrored*** offshore
- Hence, WPPs can provide frequency control through HVDC with ***communication-less*** scheme
- Fast control actions are inhibited by ***ramp rate limiters*** in the WPP
- In a P2P connection, communication-based and coordinated solutions are ***equivalent***, as far as ***frequency control and inertial response*** are concerned

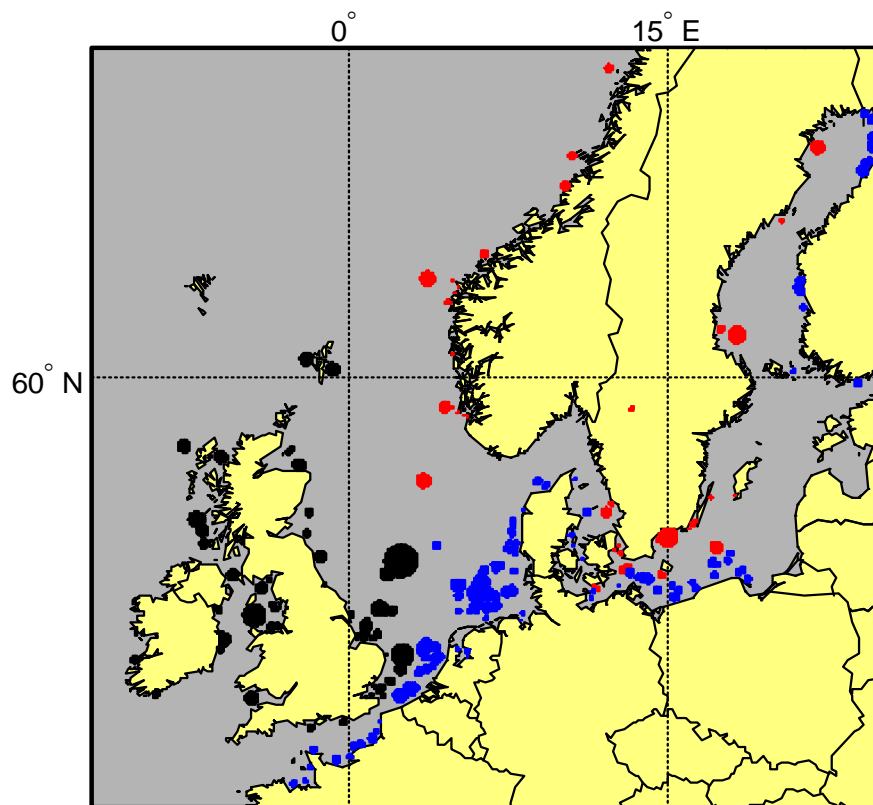
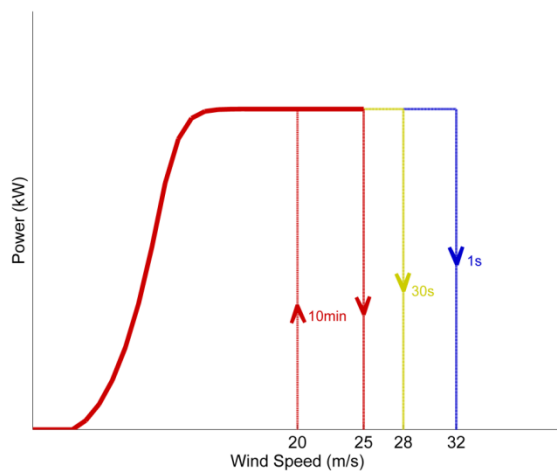
## Consortium and budget

**10 European Member States  
1 Associated Country**



## Demo 4 - The challenge

Synchronous Area	2020	2030
	MW	MW
Continental	21,421	57,685
Nordic	4,924	14,669
GB	13,711	33,601
Ireland	1,419	3,219

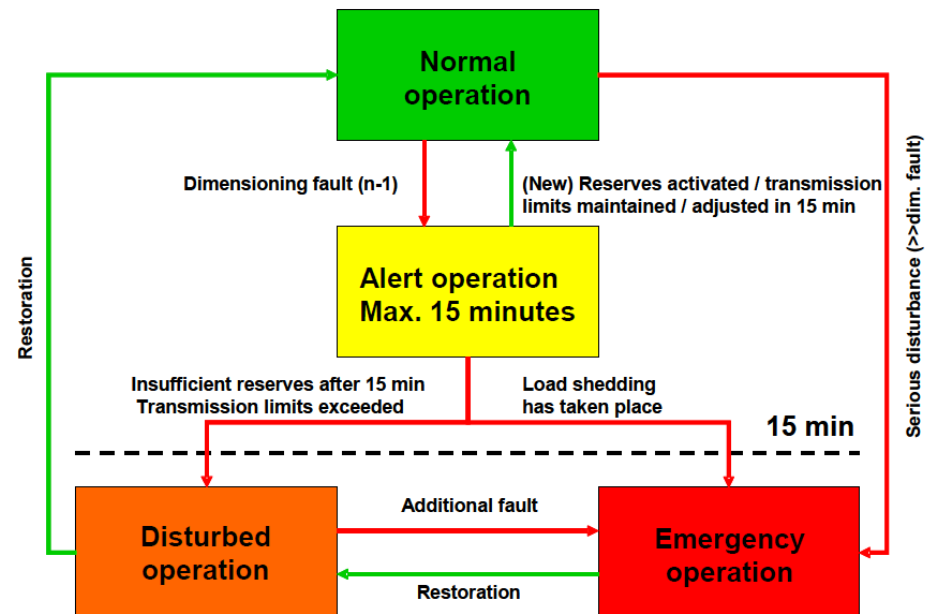


2030 map

# Large scale challenge: Adequacy of primary reserves

- There must be sufficient primary reserves in the power system synchronous area to replace lost production corresponding to dimensioning fault
- This brings power system from normal state to alert state
- Frequency restoration (secondary / tertiary) reserves will return system to normal state in 15 minutes
- Larger faults (loss of generation) may bring system into disturbed (or emergency) state
- Therefore, maximum 15 minute wind power forecast errors are essential to ensure adequacy of primary reserves

Synchronous Area	Dimensioning faultt
	MW
Continental	3,000
Nordic	1,200
GB	1,800
Ireland	500



Nordic grid code 2007

# Upscaling results and conclusion

- Result for **2020** indicates that there is **sufficient primary reserves** with current dimensioning fault to cover offshore wind power variability in the four main European synchronous areas
- Result for **2030** indicates that there is **not sufficient primary reserves** with current dimensioning fault to cover offshore wind power variability in Continental and GB synchronous areas
- PhD **poster** (Kaushik Das) on more detailed assessment in EU iTesla project

Synchronous Area	HWSD	HWEP	Dimensioning faultt
	MW	MW	MW
Continental	1,661	1,548	3,000
Nordic	480	483	1,200
GB	1,212	1,222	1,800
Ireland	224	224	500

2020

Synchronous Area	HWSD	HWEP	Dimensioning faultt
	MW	MW	MW
Continental	4,729	3,933	3,000
Nordic	1096	1082	1,200
GB	4,418	4,440	1,800
Ireland	439	438	500

2030



# Simulation of balancing (Simba)

ENERGINET/DK

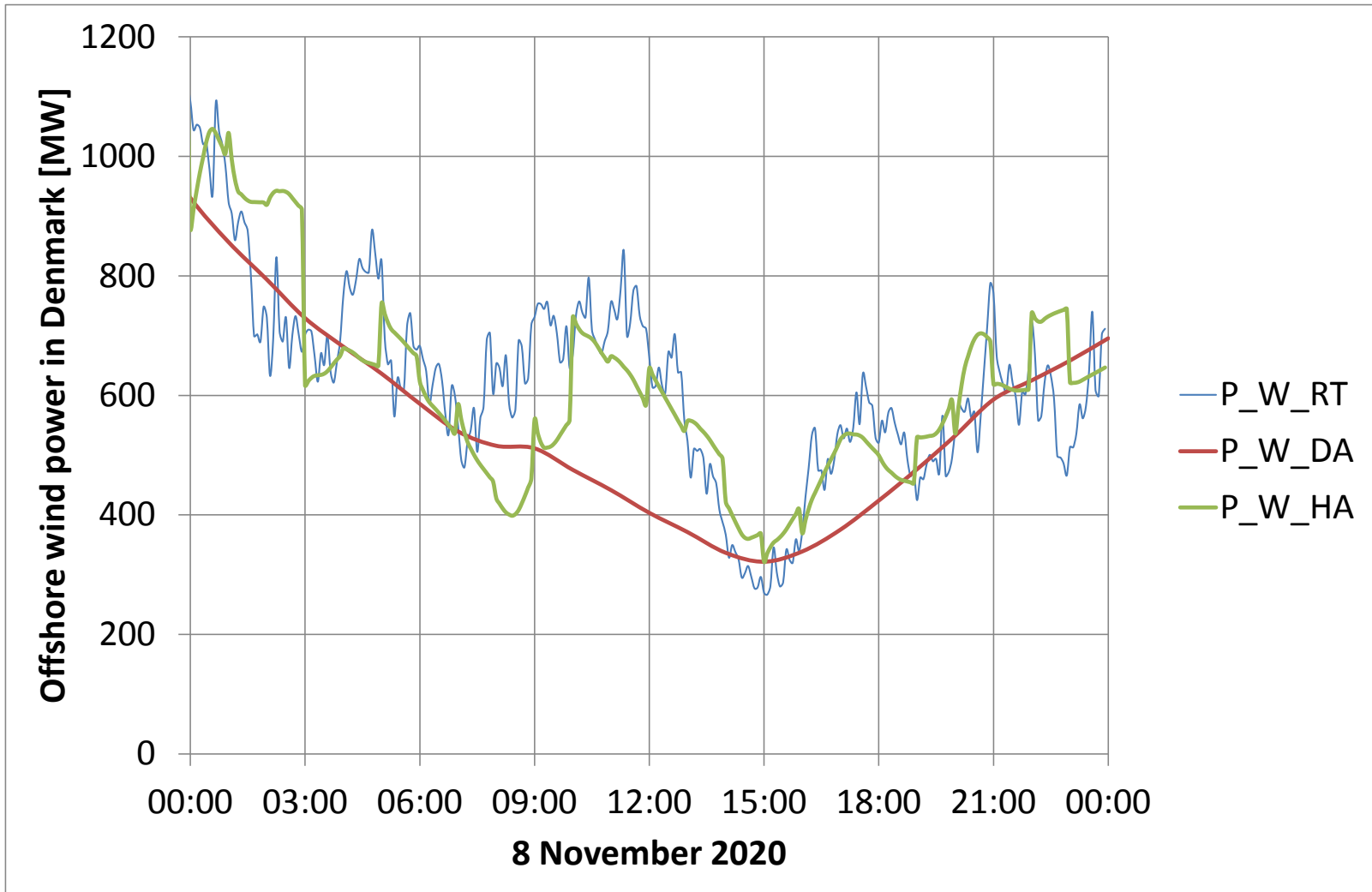


Simulation of Balancing (Simba)

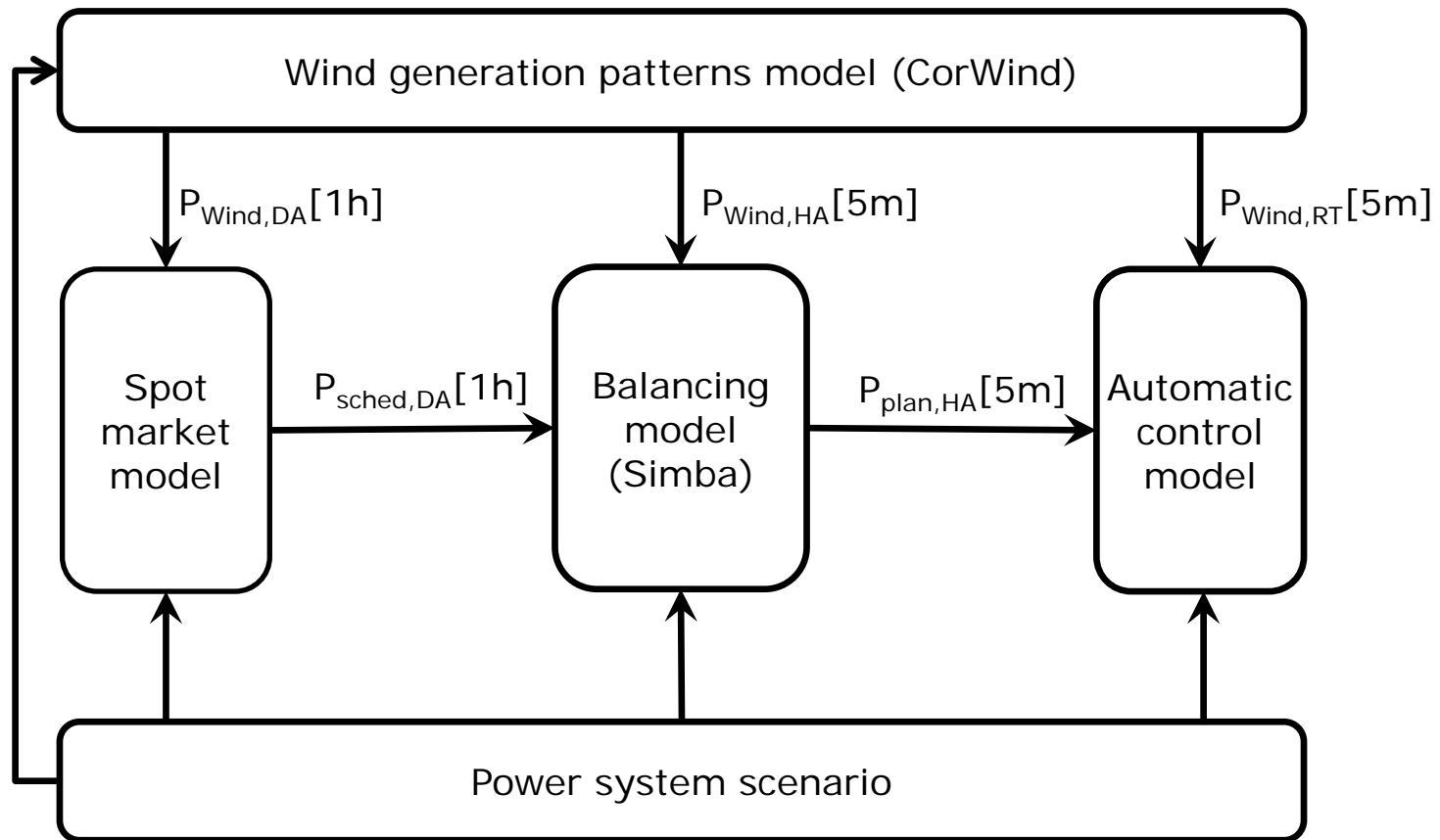
- Simba idea
  - Simulation of intra hour balancing as supplement to day ahead
  - Uses inputs from “day-ahead market model”
  - Main imbalance included today is from wind
- Applications of Simba
  - Planning of investment
  - *Assessment of new market designs (e.g. towards real time)*
  - *Assessment of cost / value of reserves*
  - *Assessment of needs for reserve capacities*
  - *Economic optimisation of system services*
  - Assessment of flexible demand support to system balancing

# CorWind

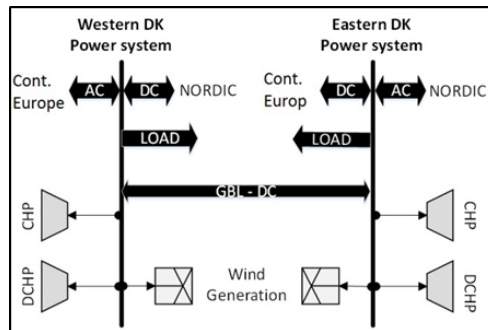
## Simulation of wind power fluctuations and forecast errors



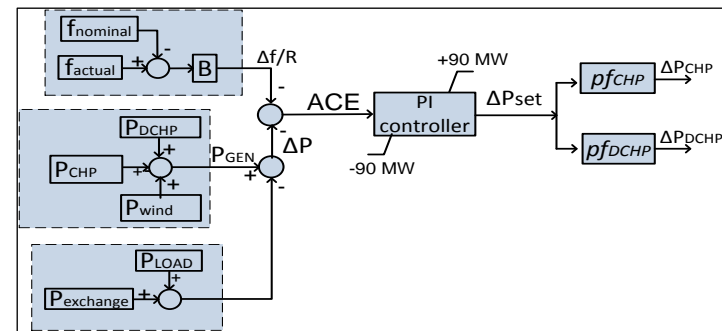
# Modelling chain: Spot market – balancing – automatic frequency control



# Automatic Generation Control in a power system with high wind power penetration – Danish case study

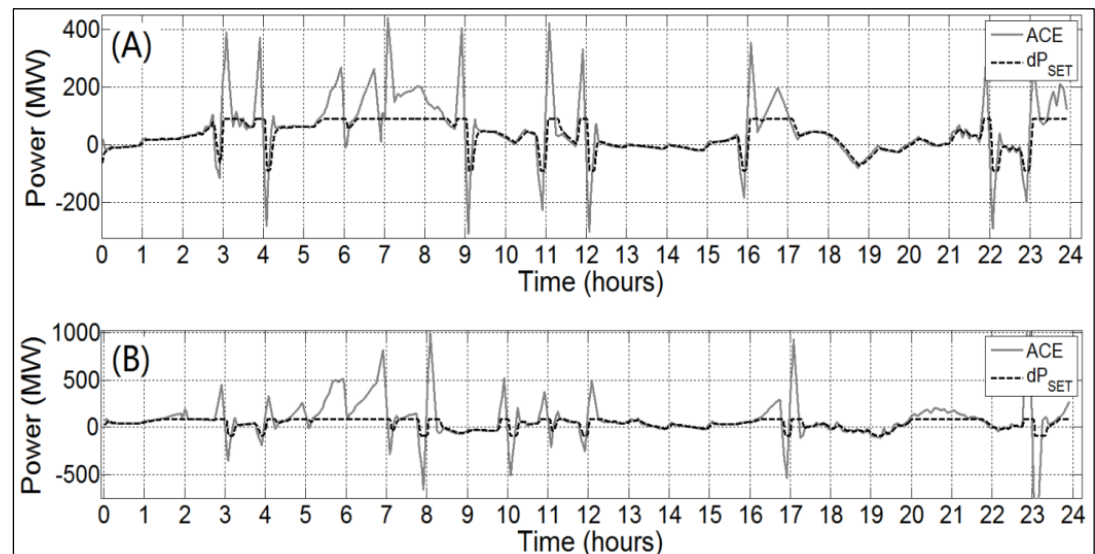


Model overview

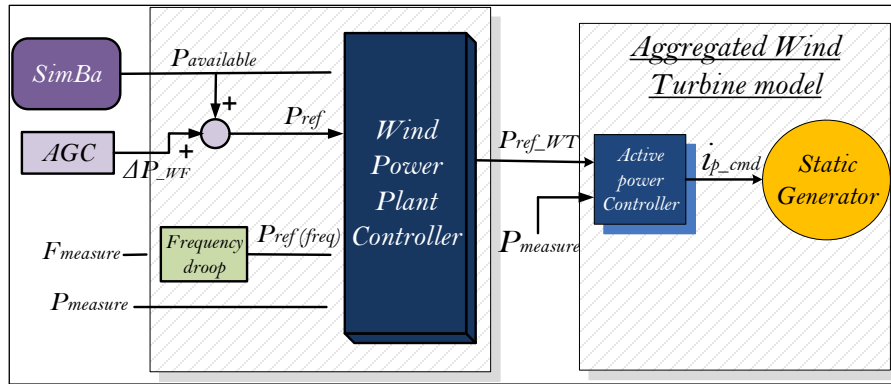


AGC model

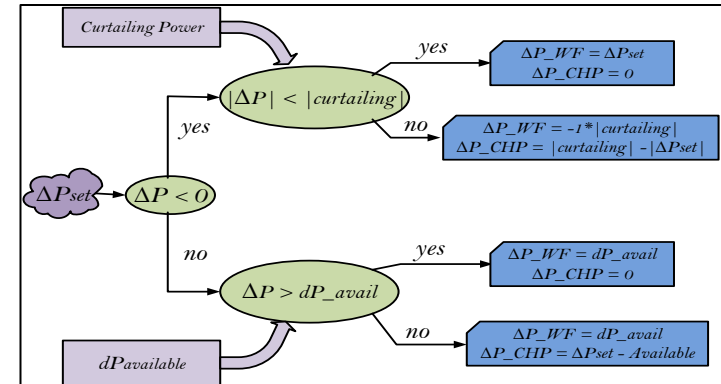
Result: simulated AGC performance



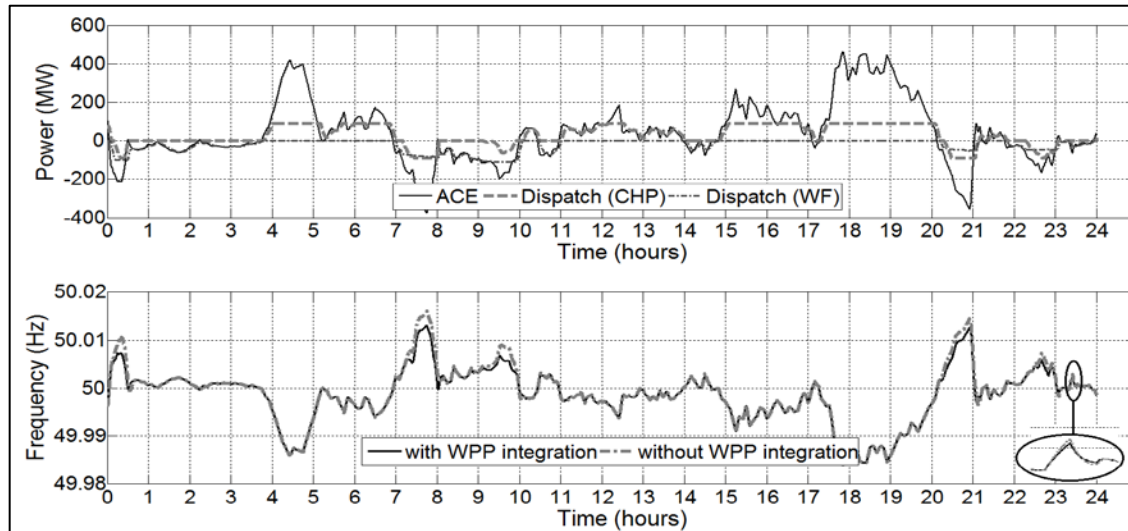
# Wind Power integration into the Automatic Generation Control of power systems



Aggregated WPP model



Secondary (AGC) dispatch with wind



More details in  
**poster**  
Abdul Basit

# Summary and reflections on technical capabilities

- *WPPs can provide basic ancillary services* and replace conventional power plants
- Also possible to provide *enhanced ancillary services* – emulating synchronous generators (inertia-like response, power oscillation damping and synchronizing power)
  - ... but is this the optimal solution in future systems?
- Ancillary services can also be provided from **HVDC** connected WPPs

# Economic incentives and barriers

- Incentives:
  - Technical requirements for grid connection!
  - Higher prices for reserves than for power (e.g. low – and even negative power prices)
  - Co-generation with other production technologies (ramp support)
  - Enables higher wind power penetration
- Barriers:
  - Symmetric (up/down) requirement (Spain – TWENTIES)
    - Downwards reserves from WPPs is feasible with high penetration
    - ... loads are more feasible as upwards reserves
  - Length (= prediction horizon) of reserve products
  - Development costs for new products
  - Additional hardware costs
  - Verification needs for new products –certification costs



# TPWind Technology Platform

## New strategic research agenda (SRA) / Market deployment strategy 2014

- Issues – very similar to REserviceS
  - Frequency support
  - Voltage support
  - System restoration support
- Research priorities
  - Further ***development of enhanced wind power capabilities*** from wind turbine level up to cluster level, including the related design tools and models;
  - ***Testing and verification*** of frequency and voltage capabilities, and methods of proving compliance of new solutions for advanced capabilities with Grid Codes and standards;
  - ***Harmonisation, standardisation and interoperability*** of methods and technologies for delivering ancillary services with wind power.

# Next steps to allow further penetration of wind into European grids?

- Researchers
  - **Propose strategies** for ancillary services from wind and other sources to ensure system stability with massive scale wind power
    - Special focus on power system security with increasing levels of **non-synchronous generation**
    - Not necessarily emulation of synchronous generators – other **smarter solutions!!**
  - Develop and implement **new controls** in simulation tools
  - **Simulation based validation** of ancillary services from wind
  - Develop **tools to assess the value** of new ancillary services
- Developers / owners
  - **Assess** the **value** of new ancillary services
- System operators
  - **Validate and implement** strategies to ensure system security
- Turbine / plant manufacturers
  - **Develop and implement** new ancillary service capabilities in full WPP scale